ERRATA

page iv - paragraph 3 . . . . three alevin densities (8,000/m^2, 11,500/m^2) should read

. . . . three alevin densities (8,000/m^2, 11,500/m^2 and 15,000/m^2)

Incubation of Chinook Salmon in Keeper Channels at Robertson Creek Hatchery

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INCUBATION OF CHINOOK SALMON IN KEEPER CHANNELS AT ROBERTSON CREEK HATCHERY

by

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ABSTRACT

Britton, E.W., W.E.McLean, and C.Beggs. 1982. Incubation of Chinook Salmon in Keeper Channels at Robertson Creek Hatchery.

Attempts are being made to incubate chinook salmon in gravel lined concrete raceways (keeper channels). A simple two factor experiment was designed to test three alevin densities (8,000/m^2, 11,500/m^2) and two levels of flow (136 L/min and 273 L/min). Migration of alevins towards the upstream ends of the channel was first observed seven days after hatch and continued until release. It was necessary to remove alevins from all but the high flow-low density case in order to avoid excessive losses. An optimal channel loading is between 8,000 chinook eggs/m^2 and 11,500 eggs/m^2. A flow of 273 L/min at the lowest density gave the most satisfactory results. Particular attention must be paid to keeper channel construction in order to avoid local turbulence.

RÉSUME

Le présent rapport porte sur des essais d'incubation de saumons quinnats dans des bassins bétonnés du type allongé, dont le fond est recouvert de gravier (canaux d'alevinage). Une expérience portant sur deux facteurs a été conçue afin de tester trois densités d'alevins (8 000/m2, 11 500/m2 et 15 000/m2) et deux taux de débit (136 L/min et 273 L/min). La migration des alevins vers la partie supérieure du canal a été observée pour la première fois sept jours après l'éclosion et s'est poursuivie jusqu'à la mise en liberté. Des alevins ont dû être enlevés de tous les bassins sauf celui où le débit était élevé et la densité faible, afin de prévenir des pertes excessives. La charge optimale d'un canal se situe entre 8 000 et 15 000 oeufs de saumons quinnats par m2. Les meilleurs résultats ont été obtenus avec un débit de 273L/min à la plus faible densité. On doit porter une attention particulière à la construction des canaux d'alevinage afin d'éviter la turbulence locale.

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INTRODUCTION and METHODS

Incubation of chum salmon alevins (Oncorhynchus keta) in gravel lined concrete incubation channels, commonly referred to as keeper channels, is a well established fish culture technique in Japan and has recently been applied in some salmon hatcheries in British Columbia. Keeper channels offer several advantages over conventional incubation methods. These include minimal labour requirements, the provision of a substrate environment, a suitability to systems with moderate silt load and the opportunity for volitional release of buttoned up fry into the rearing ponds.

Attempts are being made to apply this technique to chinook salmon (Oncorhynchus tshawytscha) at Robertson Creek hatchery. Since previous experience is limited, it is necessary to develop flow and density criteria for the incubation of this species.

A simple two factor experiment was designed to test these parameters on 1981 brood chinook salmon. In each of six identical keeper channels a flow of 136 L/min (30 I. gal./min) was established and densities of 8,000 eggs/m^2, 11,500 eggs/m^2 and 15,000 eggs/m^2 were loaded at each flow. The six resulting combinations were referred to as low flow-low density, (LFLD), high flow-low density, (HFLD), low flow-medium density, (LFMD), high flow-medium density, (HFMD), low flow-high density, (LFHD), and high flow-high density, (HFHD). Dissolved oxygen levels were monitored continually in the low flow-high density case with a Leeds and Northrup dissolved oxygen meter and probe. Readings were made occasionally in the other channels as well.

The keeper channels are 1.9 meters wide and 11.6 meters long with a 0.2% slope. A single layer of rounded gravel was distributed evenly over the channel bottom. Gravel used in the experiment was screened commercially under specifications calling for the majority of the gravel to be greater than 3.175cm (1.25 inches). Two 50 kg. gravel samples were analyzed by passing the gravel through a number of standard screens. The fraction falling in a given size range was weighed and expressed as a percentage of the total sample weight (Table 1).

Table 1. Gravel size distribution

Size range	% by weight
Greater than 3.81 cm (1.5 inch)	15.0
3.175 cm - 3.81 cm (1.25 inch)	21.8
2.54 cm - 3.175 cm (1 inch - 1.25 inch)	29.2
1.905 cm - 2.54 cm (0.75 inch - 1.0 inch)	21.1
Less than 1.905 cm (0.75 inch)	12.9
	100.0

Water level in the keeper channels was controlled by means of a 2x6 dimension stop log at the outflow (1 5/8 in x 5 1/2 in or 4.1 cm x 14.0 cm). This maintained a water depth above the gravel surface of about 9 cm (3 1/2 in).

The water velocity (U) averaged over a particular cross sectional area is related to the flow (Q) and the cross sectional area (a):

$$U = 16.67 \frac{Q}{a}$$

where: U = water velocity (cm/sec)
Q = water flow (L/min)
a = cross sectional area at the point of interest (cm^2)

Assuming a cross sectional area of 1710 cm^2 (190 cm x 9 cm), the average velocities in the high and low flow treatments were calculated to be 2.66 cm/sec and 1.33 cm/sec respectively.

As the keeper channels were 11.6 meters in length, each channel contained 1.984 m^3 of water at any one time (11.6 m x 1.9 m x 0.09 m). At a flow rate of 136 L/min the exchange rate (r) and the mean residence time (t) were 4.1 exchanges/hr and 14.6 minutes respectively. At a flow of 273 L/min the mean residence time was 7.3 minutes (8.2 exchanges per hour). These values were calculated from:

$$t = \frac{V\ 1000}{Q} \qquad \text{and} \qquad r = \frac{60}{t} = \frac{Q\ 0.06}{V}$$

where: t = mean residence time (min)
r = exchange rate (exchanges/hr)
V = water volume (m^3)
Q = flow (L/min)

The channels were loaded on December 22, 1981 by distributing eggs at the "eyed" stage (468-492 ATU) onto vexar screens submerged 5.0 cm below the water surface. On hatching, the alevins could swim downward through the screen into the gravel. Egg mortality was easily assessed after hatch was complete and screens removed. Alevins were incubated in the channels to the "button up" stage at which time the downstream screen was removed and swim-up fry were free to exit downstream into a screened pen submerged in the rearing channels. Fry were weight counted from the pen into the rearing channels. Since it was necessary to rear fry from production incubators in the same rearing facility as those from the keeper channels, it was not possible to observe experimental fry as a distinct group after migration into the rearing facility.

RESULTS

At the time the channels were loaded with eggs, the average daily water temperature was 5.5°C and the dissolved oxygen level was close to saturation (11.0 mg/L). There was a light silt load which settled out and "dusted" the eggs over the upstream 2 m of channel. Water velocity was apparent in the upstream 2 m of the high flow channels

and in the first meter of the low flow channels, but was imperceptible throughout the remaining sections.

Rapidly falling water temperatures were recorded over the next 16 days to a low of 1.5°C on January 6, accompanied by a corresponding increase in dissolved oxygen to 13.0 mg/L. At the end of this cooling trend, total hatch was estimated to be less than 2%. Egg mortality was essentially zero during this period. Water temperatures increased from January 7 to January 12 and stabilized at 4.4°C for the remainder of the experiment. (Figure 1).

The initiation of hatching was closely associated with the period of increasing water temperature, so that by January 12 (545 ATU) an estimated 50% of hatching had occurred. Dissolved oxygen levels fell as the water warmed but remained at saturation level. On January 9 the dissolved oxygen concentration at both the inflow and outflow was 12.7 mg/L; there was no apparent oxygen consumption by the hatching alevins.

This could have resulted from the combined effects of re-aeration at the air/water interface and/or a low alevin metabolic rate. It could also have resulted if the flow characteristics of the channels were such that the majority of the incoming water passed over the alevins and was discharged essentially un-used.

In order to more fully understand the condition in the channels, dissolved oxygen was monitored in the surface flow, at mid-depth and at the bottom of the water profile at four locations in the high density and mid-density channels. Figure 2 illustrates the slightly depressed level of saturation at the bottom of the water profile and suggests incomplete mixing between the bottom and upper two layers of water. At this time, however, dissolved oxygen levels were acceptable throughout the channels and presented no hazard to the incubating alevins.

Migration of alevins toward the upstream end of the channel was first observed in the high density-low flow case on January 14 (555 ATU). Alevins travelled upstream through a hollow pipe used to support the egg screen and bunched up just beyond the upper end of the pipe. Black plastic was placed over the wooden channel covers in an attempt to slow migration by darkening the environment, but this seemed to have little effect. Since the water flow in the upper section of channel was more turbulent, alevins in this area were forced to swim against a current. This became apparent as displaced alevins continued to move upstream to the head of the channel.

The upstream crowding phenomenon developed to some extent in each channel but was judged to be insignificant in the low density channels. Slightly elevated densities developed at the bottom ends of the channels. Alevins also congregated in areas where imperfections in channel design created local turbulence. The degree of crowding was proportional to alevin density while the rate of crowding was greatest in the high flow channels.

Alevin density at the head of the channels remained high until migration into the rearing channels had substantially reduced the numbers in each keeper channel and the channel covers were removed. Both lethal

and sublethal effects are attributed to the crowded environment. On January 23, alevins from the head, middle and tail of the low flow-high density channel were randomly sampled and 50 alevins were weighed and measured from each group. They averaged 0.426 g/alevin, 0.451 g/alevin and 0.492 g/alevin respectively. The alevins at the bottom of the keeper channel were significantly larger (at the 0.025 level) than those at the middle or top of the channel.

This suggested that more efficient utilization of yolk and more rapid growth occurred in areas of lower density. Alevin length also increased as one sampled further downstream: mean lengths were 2.80 cm, 2.86 cm, and 2.91 cm respectively.

Density increased in the upstream sections until alevins were piled to a depth of 6.4 cm in the high density channels and 3.0 cm in the mid-density channels. Such a condition was judged to be very undesirable and likely to produce a fry of inferior quality even if mortality did not occur. Suffocation in the lower layers of alevins first became apparent on January 26 (605 ATU) in the high and mid-density channels and developed until dead alevins were distributed over the first two meters of the high density channels to a depth of about 1.5 cm. It was impossible to quantify the number dead. Large losses were also sustained in the mid-density channels. Dissolved oxygen readings of less than 1.0 mg/L were obtained in the most severely affected areas.

Since it was clear that conditions in each of the high density and mid-density channels were unsatisfactory, alevins were removed from these channels and incubated elsewhere in order to avoid further mortality. Only those alevins judged to be in an overcrowded condition were removed and their numbers, based on weight estimation, are given in Table 2. These values are an indication of the severity of the crowding problem in each channel.

Table 2. The number of alevins removed from each keeper channel in order to avoid excessive suffocation.

Treatment	Alevins Removed	% of Alevins Removed
HD LF	77,500	24%
HD HF	78,000	24%
MD LF	35,000	14%
MD HF	35,000	14%
LD LF	16,000	9%
LD HF	0	0%

The initial loading was therefore reduced over the course of the experiment by the indicated percentage plus an unknown number of dead. These figures reflect the severity of crowding in each treatment.

Throughout the incubation period dissolved oxygen levels remained

above 10 mg/L at the outflow. In the gravel substrate, readings were between 8.0 mg/L and 10.0 mg/L, indicating an incomplete exchange between layers. Harmful levels, however, were observed only in the crowded area.

Buttoned-up fry were released into the rearing facility from April 7 to 15 (970.6 to 1026 ATU) by removing the screen at the outlet, removing the channel covers, and allowing the fry to migrate voluntarily. At release, fry had a thin slit of yolk still visible along the abdominal wall. Fry were bulk weighed during emigration and averaged 0.59 g/alevin.

DISCUSSION:

The practicality of keeper channels for incubating chinook salmon in a production facility is brought into question by the low density at which alevins begin to crowd. This response must be avoided if the advantage of raising alevins in a substrate environment is to be maintained. Work done at Puntledge Hatchery (Courtenay B.C.) indicates that density is a factor in the crowding phenomenon and that upstream movement is not simply a response to water flow. In this trial, eyed chum eggs were loaded into the bottom section of a keeper channel at a density exceeding the recommended level. Alevins were prevented from moving into the upper sections by a screen. When crowding occurred the screen was removed and alevin were permitted to migrate until a lower density was reached. At this point upstream movement ceased and alevins settled into the substrate (Harry Genoe, pers. comm.)

It has been suggested that with excessive densities, alevins are displaced into the water stream above the gravel and, due to their streamlined shape, become orientated facing upstream much as a weather vane orients into the wind. Swimming activity results in upstream movement, (C. Lam pers. comm.). This model is compatible with the observed relationships between loading density and water flow, and the crowding phenomenon.

CONCLUSION:

1. Particular care must be given to keeper channel design and construction in order to aviod local turbulence in flow. The inflow structures are especially critical: flows must be introduced uniformly over the full width of the keeper channel. If flows are introduced non-uniformly, alevin suffocation can result. It is also important to have a uniformly flat channel bottom without depressions or undulations.

2. Under the conditions of this experiment, the keeper channel loading which would maximize use of space and flow while maintaining fish health, is between 8,000 chinook egss/m^2 and 11,500 chinook eggs/m^2.

3. Of the two flows used on this experiment, the higher flow (273 L/min) gave the most satisfactory results. This factor, however, does not appear to have as pronounced effect on fish health as loading density. In areas where water supply is limited, flow as low as 136 L/min can be safely applied.

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Fig 1. Dissolved Oxygen, Temperature, Accumulated Thermal Units and Percent Hatch are illustrated, as observed in the High Density - Low Flow Channel. Initiation and Conclusion of the Volitional Emigration into the Rearing Pond is also shown.

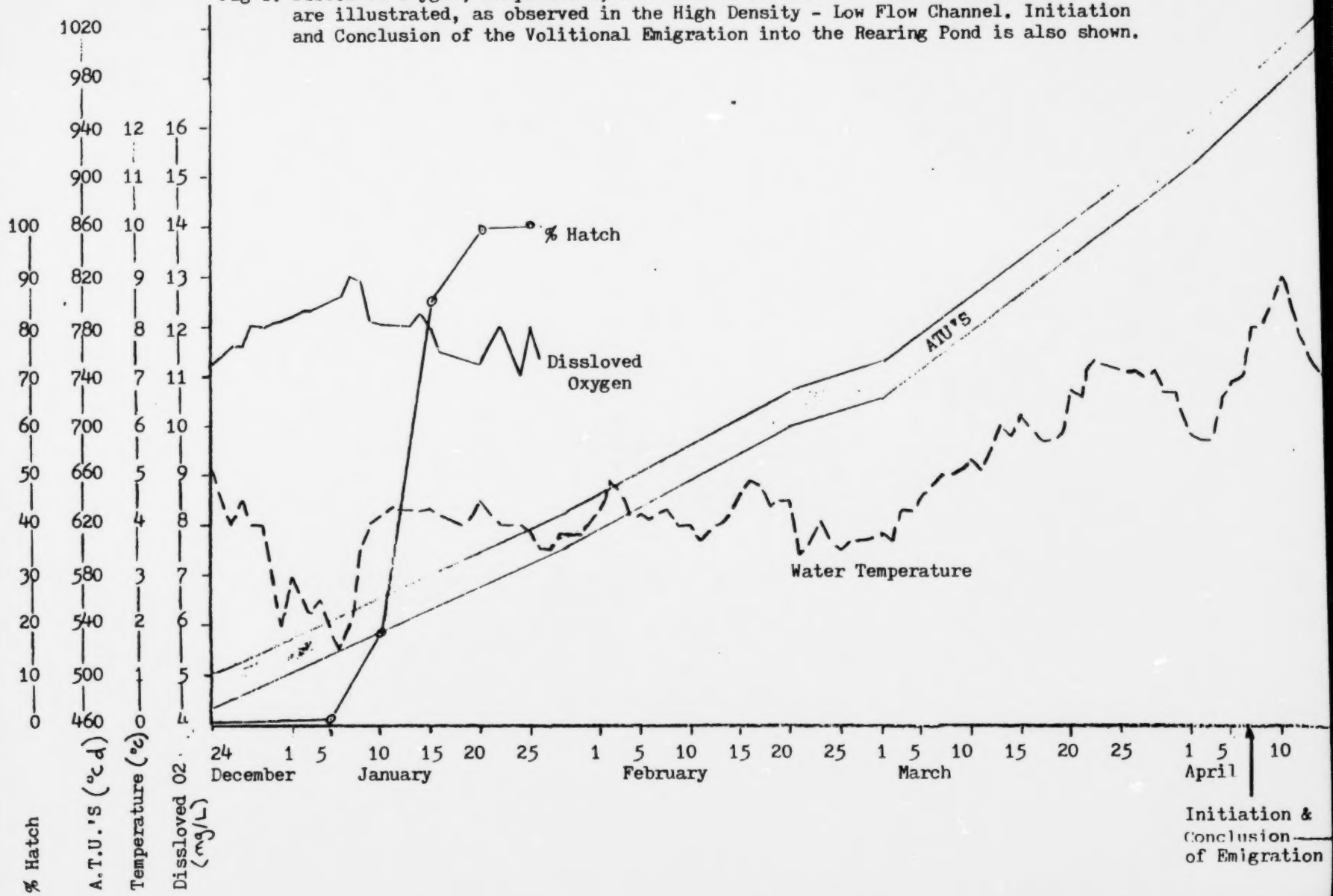

Figure 2. Average dissolved oxygen profile (four locations) on Jan. 13, 1982. Water temperature 4.8°C